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In-Vehicle Monitoring and Analysis System for Driver's Enervation

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Abstract— **Human error is still one of the most frequent causes of catastrophes and ecological disasters. This paper presents a new approach towards automobile safety and security. In the field of an automotive research, a method to monitor and to detect a fatigue/drowsy or drunken driver has been studied for many years. Previous research uses sensors or voice or image processing to detect driver's expression. This system approaches for real-time detection of physiological data and fatigue state and thereby, the Introduction of "Automated System for Monitoring and Detection of Driver's Fatigue" comes into the picture to provide supervision for individuals during the act of driving. This system consists of sensors installed in the steering wheel and the input to the system is a continuous stream of signals from the sensors. The system monitors the driver's eyes to detect micro -sleeps (short periods of sleep lasting 3 to 4 seconds) by using a proposed camera of two IR illuminators and provides technical means for monitoring and recording the driver's basic physiological parameters using various sensors. The system can analyze the eyes lid movement, pupil detection, percentage closure of eyes (PERCLOS) variation in pulse rate, temperature, pressure and galvanic skin response from the driver compute it as well as compare signal. Accordingly, we can obtain the driver's fatigue level and physiological state based on the response signals from various sensors in order to alert the driver**

Keywords- Fatigue, physiological parameters, sensors, micro sleep, driver monitoring system architecture.

I. INTRODUCTION

Driver fatigue resulting from sleep deprivation or sleep disorders is an important factor in the creasing number of accidents on today's roads. Likewise, the accidents due to health related issues also add on to the accidents rate. This system provides technical means for monitoring and recording the driver's basic physiological parameters, oncoming fatigue and issue timely warning which could help to prevent many accidents. The system provides a strong foundation in the field of monitoring the physiological conditions like saccadic activity, pulse rate, blood oxygenation level, galvanic skin response, body temperature and pressure. It also checks above parameters against abnormal (e.g. a low level of blood oxygenation or a high pulse rate) or undesirable (e.g. a longer period of lowered visual attention) values and triggers user-defined alarm when necessary. These technologies monitor usually the real time bio behavioral aspects of the driver; for example, eye gaze, eye closure, pupil occlusion, head position and movement, and heart rate. The eye blink frequency increases beyond the normal rate in the fatigued state. In addition, micro sleeps that are the short periods of sleep lasting 3 to 4 seconds are the good indicator of the fatigued state. The corrective measures are taken care of by an eye tracker which is used to detect the pupil using IR light sources in order to ensure that the driver's concentration lies on the road. An alarm will be voiced if the driver's concentrations lapses for over 3 seconds while the car is in motion. Palm sensors installed in the steering wheel feed information on the live data of physiological parameters. This system compares the current data with the raw data stored in the database. After comparison of the data according to the age group the driver falls in, he/she is alerted with a pre-defined alarm system which alerts him/her in the event of driving.

The objective of this paper is to review and discuss some of the activities currently underway to develop unobtrusive, in vehicle, real drowsy driver detection and physiological monitoring system and to present a format by which these technologies may be evaluated for use in transportation operations. Accordingly the driver must respond to the message that is displayed. The propose system uses sensor network for detecting the Driver's Fatigue and makes use of GPS system to make calls to the nearby hospitals in case of an emergency situation.

II. SYSTEM OVERVIEW

The system monitors the status of the driver's visual attention through measurement of saccadic activity. The system checks parameters like pulse rate, temperature, blood oxygenation, against abnormal and triggers user defined alarms. It consists of mobile measuring device and a central analytical system**.** The mobile device is integrated with Bluetooth module providing wireless interface between sensors and the central unit as shown in Fig. 1 ID cards assigned to each of user and adequate user profiles on the central unit side to provide necessary data personalization.

The system consists of the following:

- Mobile measuring device (DAU)
- Central System Unit (CSU)

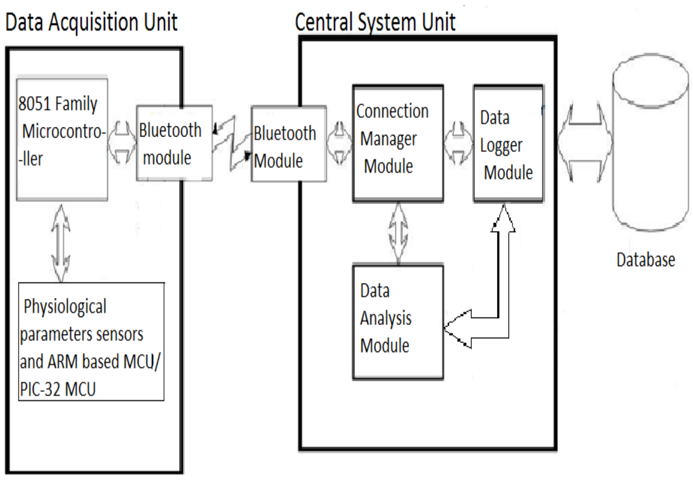


Figure 1. Overall System Diagram

III. HARDWARE COMPONENTS

There are two main components of the system. They are as follows:

A. Data Acquisition Unit

DAU is a mobile part of the system. Its main task is to fetch physiological data from the sensor and send it to the central system to be processed. To accomplish the task, the device must manage wireless Bluetooth connections. Personal ID cards and PIN codes provide driver's authorization. The Atmel 89C52 is the microcontroller which forms the core of the DAU. It enhances bidirectional serial data transmission. The 89C52 is chosen since it has well established industrial standards and it provide necessary functionality. It has a very high speed serial port which makes the serial data transmission smooth. All the DAU software is written in the 8051 assembler code. This ensures highest program efficiency and lowest resource utilization. User authorization is carried on using a simple 5-key keyboard, a small LCD display and a beeper.

B. Hardware Specification

Atmel 8952 microcontroller is the core of Data Acquisition Unit is a well-established industrial standard and provides necessary functionality (i.e. high speed serial port) at a low price. The Fig. 2 shows the other DAU components.

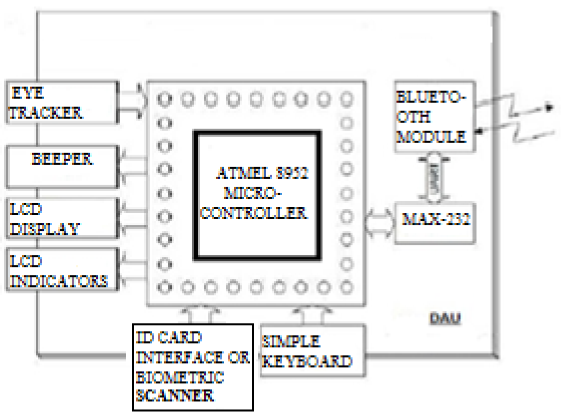


Figure 2. Data Acquisition Unit (DAU) hardware diagram

- The alphanumeric LCD display (two 8-character lines) helps the driver enter PIN code.
- It also provides further information on the health status of the user.
- The LED indicators show the results of built-in self-test and the state of wireless connection.
- The simple keyboard is used to react to incoming events (e.g. to silence the alarm sound) and to enter PIN code while performing authorization procedure.
- ID card interface helps connect the driver's personal identification card to the DAU. After inserting the card, authorization procedure begins as cited in Ref [6].

Each ID card is programmed to contain driver's unique identity, his/her date of birth and device access PIN code the driver enters on inserting his ID card for the authorization of the system.

The Data Acquisition Unit comprises several hardware modules:

- Beeper and LED indicators, 6 AA batteries and voltage level monitor.
- ARM based MCU (highly advanced) or PIC-32 MCU for storing saccadic activity of the driver.
- Atmel 89C52 microcontroller - system core.
- Bluetooth module (based on ROK101008)
- Small LCD display.
- 24C16 - I2C EEPROM (on a removable ID card) and a biometric scanner.

C. Central System Unit

Central System Unit hardware is the second peer of the wireless connection. The box contains a Bluetooth module and sufficient memory to store the information in the database. To program driver's personal IDcards, a simple programming device is developed. Inside the CSU, there is Atmel 8951 microcontroller, which handles UART transmission and I^2C (Inter Integrated Circuit) EEPROM (ID card) programming.

1) Software

The main task of this system is to look after driver's physiological condition. To assure instant reaction on his/her condition change, the software performs real time buffering of the incoming data, real-time physiological data analysis and alarm triggering. This system comprises several functional modules. System core facilitates the transfers flow between other system modules (e.g. transfers raw data from the Connection Manager to data analyzers, processed data from the data analyzers to other controls, other data analyzers, data logger etc.).

a) Connection Manager

It is responsible for managing the wireless communication between the mobile Data Acquisition Units and the Central System Unit. The Connection Manager handles:

- Communication with the CSU hardware.
- Establishing Bluetooth connections.

- Connection authentication.
- Incoming data buffering.
- Sending alerts.

b) Data Analysis Module

It performs the analysis of the raw sensor data in order to obtain information about the driver's physiological condition. The separately running Data Analysis module supervises driver's condition. The module consists of a number of smaller analyzers extracting different types of information.

The most important analyzers are:

- Custom analyzers - recognize other behaviors than those which are built-in the system. The new modules are created using decision tree induction algorithm.
- Pulse rate analyzer - uses blood oxygenation signal to compute driver's pulse.

c) Data Logger Module

The module provides support for storing the monitored data in order to enable the system to reconstruct and analyze the course of the driver's health conditions. The module registers data to be stored in the database apart from the raw or processed physiological data and alerts are stored. The raw data is supplied by the related Driver Manager module, whereas, the Data Analysis module delivers the processed.

IV. FATIGUE DETECTION TECHNOLOGIES

Fatigue detection and prediction technologies are categorized into two groups as shown below:

A. Vehicle Based Performance Technologies

Vehicle-based performance technologies places sensors on standard vehicle components,(e.g., steering wheel, gas pedal) and analyzes the signals sent by these sensors to detect drowsiness as citied in Ref[7]. Other technologies measure driver's acceleration, braking, gear changing, lane deviation and distances between vehicles. Some car companies adopted this technology however the main problem with the input is that they do not really work very effectively, or at least only work in very limited situations. Some of the previous studies use driver steering wheel movements and steering grip as an indicator of fatigue impairment which cannot be concerned reliable.

B. In-Vehicle, On-Line, Driver Status Monitoring Technologies

These set of techniques aim to measure the behavior of the driver. These approaches can use Physiological Signals to understand the behavior of the system.

1) Functionality of the System

The system utilizes an individual recognition system with the help of an RFID card reader along with a 5 key keypad and an LCD Display and a buzzer. The user is asked to insert his card at all times prior to the drive. By typing in the 5-digit PIN code, the verification of the individual is completed and the system automatically establishes Bluetooth connection with the Central System Unit. With the presence of a digital clock in the DAU, the automatic updating of the driver's age takes place as he/she ages yearly. This is done to ensure that the driver's age falls in the right category no matter how many years the person is and the system is being used. Palm sensors are used such as pressure sensor, galvanic skin response sensor, temperature sensor and pulse rate sensor (Light and LDR assembly) as cited in Ref [12].

Incorporating palm sensors in the steering wheel helps detect several physiological factors as mentioned previously as cited in Ref [9]. Eye tracking devices installed in front of the driver utilizes dome or disc shaped CMOS cameras. Cameras are designed in such a way that the 2 IR light sources within them help to detect the presence of the pupil. Simultaneously, the data attained from the Eye tracker is processed under the ARM based MCU/PIC-32 MCU placed within the DAU. The car alarm system alerts the driver when there is a lapse in concentration over 3 seconds while the car is in motion. The generalized data or raw data are already stored in the database according to the various age groups.

The live data received will be compared with the raw data of the age group in which the driver falls. Here the data is sent from DAU to CSU via Bluetooth. Data comparison is done in the Central System Unit. Any abnormality in the readings. would lead to the triggering of the alarm system which would alert the driver with the problem he is facing.

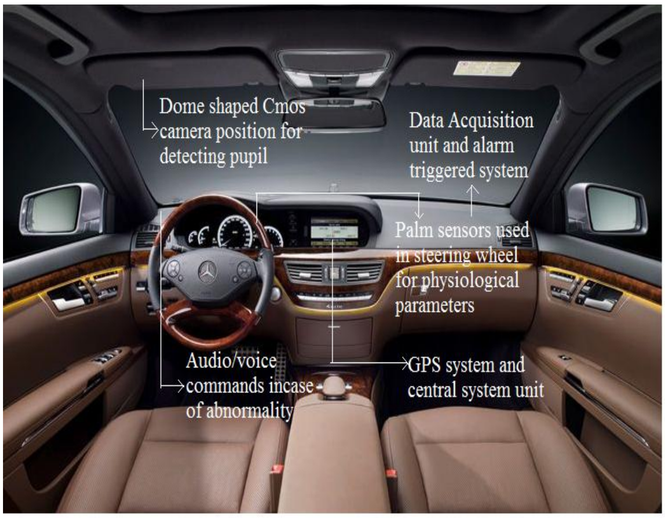


Figure 3. Actual Implementation of the system in a car

The driver would be given a choice of making a call on his own or else an emergency call would be made using the GPS system of the car. If no option is selected in a short duration, i.e. 30 secs, then an emergency call would be made to the closest hospital with the help of the GPS navigation system.

2) Design of the System

a) The device should measure what it is intended to, operationally e.g. eye blinks, and conceptually e.g., alertness.

b) The device should monitor driver behavior in real time.

c) The device should be consistent in its measurement over time, and it should measure the same event for all drivers.

d) The device should be able to operate accurately and reliably in both day time and night time illuminations conditions.

e) The device should be designed to maximize sensitivity and specificity. In other words, it should minimize missed events accurately and reliably.

f) The device should be able to operate in adverse conditions of temperature, humidity and radiations.

V. EYE DETECTION AND TRACKING

Fatigue monitoring starts with extracting visual parameters that typically characterize a person's level of vigilance The system consists of narrow angle camera focusing on the eyes and thereby monitors Eyelid and gaze movements as shown in Fig. 5. The system starts with eye detection and tracking. The goal of eye detection and tracking is for subsequent eye-lid movement monitoring and gaze determination. To this end, the person's face is illuminated using a near-IR illuminator.

The use of an IR illuminator serves three purposes. First, it minimizes the impact of different ambient light conditions, therefore ensuring image quality under varying real-world conditions including poor illumination, day, and night.

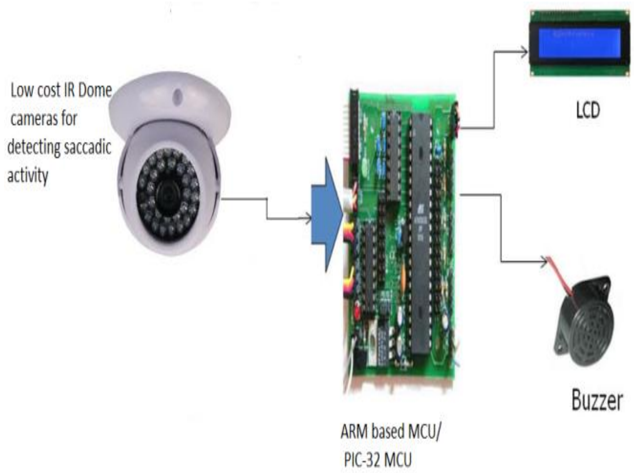


Figure 4. Proposed Fatigue Detection System

Second, it allows us to produce the bright/dark pupil effect, which constitutes the foundation for detection and tracking of the proposed visual cues. Third, since near IR is barely visible to the driver, this will minimize any interference with the driver's driving. Specifically, our IR illuminator consists of two sets of IR light-emitting diodes (LEDs), where one is placed on-axis i.e., near the optical lens and the other is placed on off-axis. Two IR illuminators are used. The similar reference is cited in Ref [2] and [6]..One is placed very close to the camera's optical axis and is synchronized with the even frames. Odd frames are synchronized with the second light source, positioned off-axis as shown in fig 6. The two light sources are calibrated to provide approximately equivalent whole-scene illumination. Pupil detection is realized by means of subtracting dark pupil image from the bright pupil image as shown in the Fig.8. After thresholding the difference, the largest connected is identified as the pupil. This technique significantly increases the robustness of the eye tracking system as cited in Ref [3].

VI. EYE-LID MOVEMENTS PARAMETER

Eyelid movement is one of the visual behaviors that reflect a person's level of fatigue. The primary purpose of eye tracking is to monitor eyelid movements and to compute the relevant eyelid-movement parameters as cited in Ref [5].Here, we focus on two ocular measures to characterize the eyelid movement. The first is Percentage of eye closure over time (*PERCLOS*) and the second is average eye-closure speed (*AECS*). PERCLOS has been validated and found to be the most valid ocular parameter for monitoring fatigue.

The eye closure/opening speed is a good indicator of fatigue. It is defined as the amount of time needed to fully close or open the eyes. Our previous study indicates that the eye-closure speed of a drowsy person is distinctively different from that of an alert person.The degree of eye opening is characterized by the shape of the pupil. It is observed that, as eyes close, the pupils start to get occluded by the eyelids and their shapes get more elliptical. So, we can use the ratio of pupil ellipse axes to characterize the degree of eye opening.

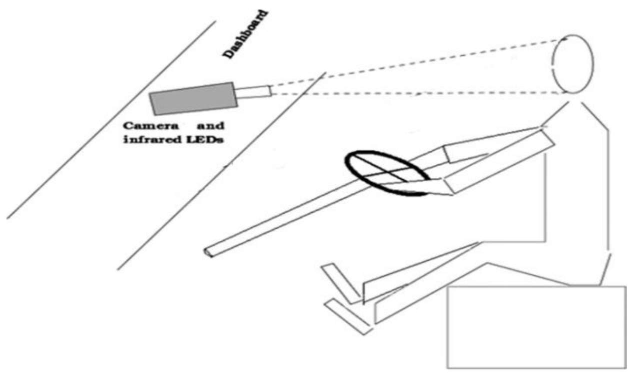
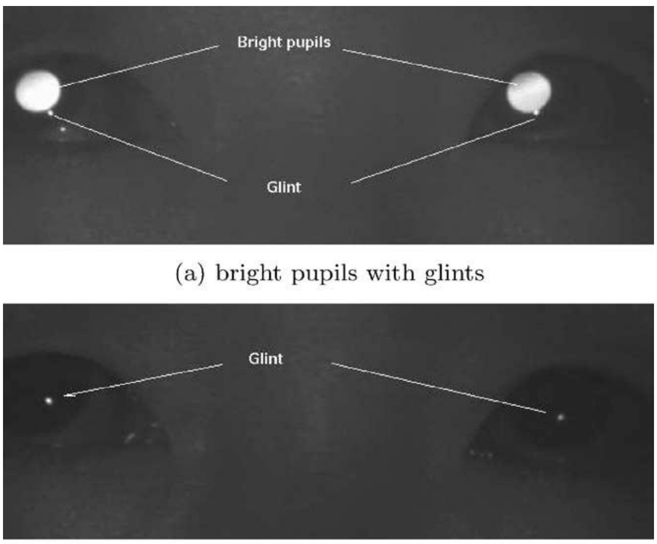


Figure 5. Overview of the driver vigilance monitoring system

The cumulative eye-closure duration over time, excluding the time spent on normal eye blinks, is used to compute PERCLOS. To obtain a more robust measurement for these two parameters, we compute their running average (time tracking) as cited in Ref [10] and Ref[1].



(a) bright pupils with glints

(b) dark pupils with glints

Figure 6. Bright and dark pupil images with glints.

(a) (b) (c)

Figure 7. a) even field image b) odd field image c) difference image

VII. AN OVERVIEW OF THE EXISTING TECHNIQUES

Technological approaches for detecting and monitoring fatigue levels of driver fatigue continue to emerge and many are now in the development, validation testing, or early implementation stages. Previous studies have reviewed available fatigue detection and prediction technologies and methodologies. One such method utilizes EEG to detect driver's fatigue but, it resulted to be very expensive o be commercialized and needs complex noise processing. In short, these all cannot reflect outer situation of a driver and cannot adapt to each user. As per theory, the average of the five facial actions that were the most predictive of drowsiness by *increasing* in drowsy states were outer brow raise, frown, chin raise and nose wrinkle.

The five actions that were the most predictive of drowsiness by decreasing in drowsy states were smile, lids tighten, nostril compress, brow lower and jaw drop. The high predictive ability of the blink/eye closure measure was expected. The present scenario as given in theory lacks technical details since it makes use of facial recognition system which might fail to give perfect results. The system tends to vary depending upon the age of the driver as shown in Fig. 8. Nevertheless, addressing these general user issues and scientific criteria is vital to ensure that any proposed device or technology is qualified for its intended purpose of monitoring. Thereby, averting motor vehicle crashes related to driver fatigue.

VIII. SYATEM ARCHITECTURE

The system will consist of three essential components as shown in the Fig. 9 They are as follows:

1) Input Unit:
   a) Sensors are used to sense the behavior of driver and
   b) An eye tracker is used for pupil detection and predicting fatigue.
2) Processing Unit:
   a) For calculating, decision making and
   b) Evaluation process, this unit is included.
3) Display Unit / Output Unit:
   a) Any abnormal activity during the event of driving is alerted using the buzzer and
   b) A Voice activated message.

IX. ALGORITHM FOR THE SYSTEM

a) Start

b) Insert ID card for authorization and to establish Bluetooth connection.

c) The system will retrieve data under which the driver's age falls on.

d) The system will start to analyze the physiological parameters through sensors on steering wheel and pupil detection through an eye tracker.

e) The live data are continuously sent to DAU and CSU via Bluetooth.CSU will process and compare the live data with raw data and transfers the result to DAU via Bluetooth.

f) Step 3 and 4 is repeated until the control unit encounters an abnormality in the status of the driver.

g) In case of abnormality or any accident, the system will recognize the emergency and gives two options to the driver. One is an emergency call to the nearest hospital and another one is to call nearby acquaintance.

h) If the driver does not respond within15 secs, the GPS will automatically search for nearby hospital and will make a recorded voice call to the hospital stating the problem and location of the driver.

i) Stop.

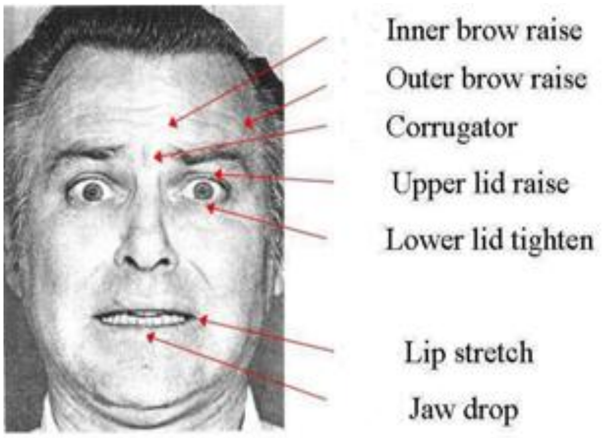


Figure 8. Facial Action Prediction

X. CONCLUSION

In this paper, it is due to the driver's fatigue and physiological conditions, traffic accidents keep with a yearly increasing of a high rate. This paper shows the new detection technique using various sensors and a proposed IR illuminator camera which is used to alert the driver on regular basis. We propose a new advanced safety model in a complete package to curb accidents in future.

XI. FUTURE WORKS

In future, we will also incorporate two cameras such as wide-angle camera focusing on the face for facial expression analysis and narrow angle camera focusing on eye for gaze determination and eye-lid movement monitoring. To improve and increase the standard of technology, we can also incorporate a multisensor which will detect eye movements, head acceleration level, position of a driver.

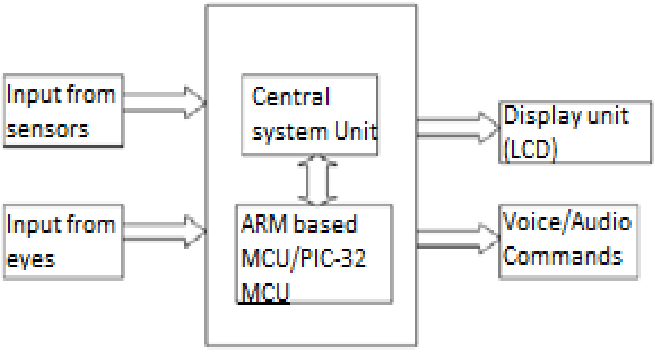


Figure 9. System Architecture for the proposed system

Utilization of the biometric fingerprint scanner offers a much more reliable interface between the driver and the system instead of an IDcard system.

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